

# **NASA Earth Science Disasters Program Response Activities During Hurricanes Harvey, Irma, and Maria in 2017**

**Jordan Bell**

*Earth System Science Center, University of Alabama in Huntsville, Huntsville, Alabama  
NASA Earth Science Disasters Response Program, Marshall Space Flight Center*

**Major Weather Events and Impacts of 2017**

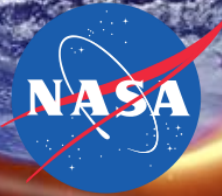


# Coauthors and Contributors

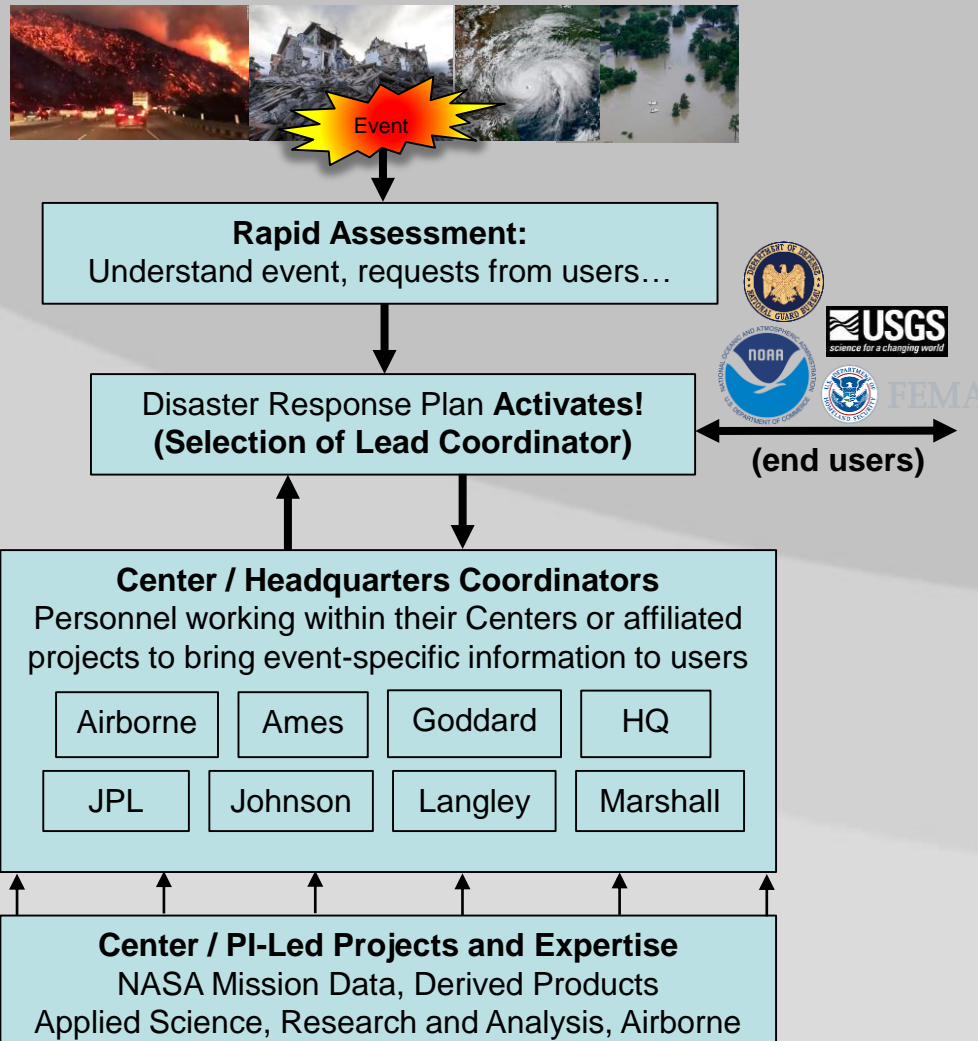


David Green, Program Manager Jessica Seepersad Carver Struve Victoria Thompson	NASA Headquarters and Applied Sciences Disasters Program
Dalia Kirschbaum, Miguel Román, Kelvin Brentzel	NASA Goddard Space Flight Center
Michael Goodman	NASA Marshall Space Flight Center
Jordan Bell, Lori Schultz, NASA SERVIR Team	University of Alabama Huntsville / MSFC
Margaret Glasscoe, Sang-Ho Yun, Susan Owen, Rashied Amini, Yunling Lou	Jet Propulsion Laboratory California Institute of Technology
William Stefanov	NASA Johnson Space Center
John Murray	NASA Langley Research Center
Franz Meyer, Kirk Hogenson, Rudiger Gens	University of Alaska Fairbanks / Alaska Satellite Facility
<i>Other partners: USGS/Hazards Data Distribution System, Int'l Charter on Space and Major Disasters, end user collaborators within DHS/FEMA, U.S. National Guard, University of Maryland, Global Flood Partnership, others.</i>	

*Some examples in this presentation contain modified Copernicus Sentinel data (2017), processed by ESA and analyzed by staff at NASA-JPL/Caltech/ARIA, NASA Marshall, and the University of Alaska Fairbanks, along with data provided by USGS/HDDS and Int'l Charter*



# Disaster Response Team Process



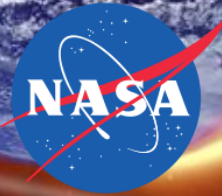
- Following a disaster event, NASA personnel at HQ evaluate to determine an appropriate degree of response from NASA Centers and partners.
- When activated, NASA Centers contribute an event coordinator to help bring together efforts throughout the agency and academic or industry partners.
- Response activities focus on providing information and products requested by partners, helping to integrate information into their decision-making process.





-

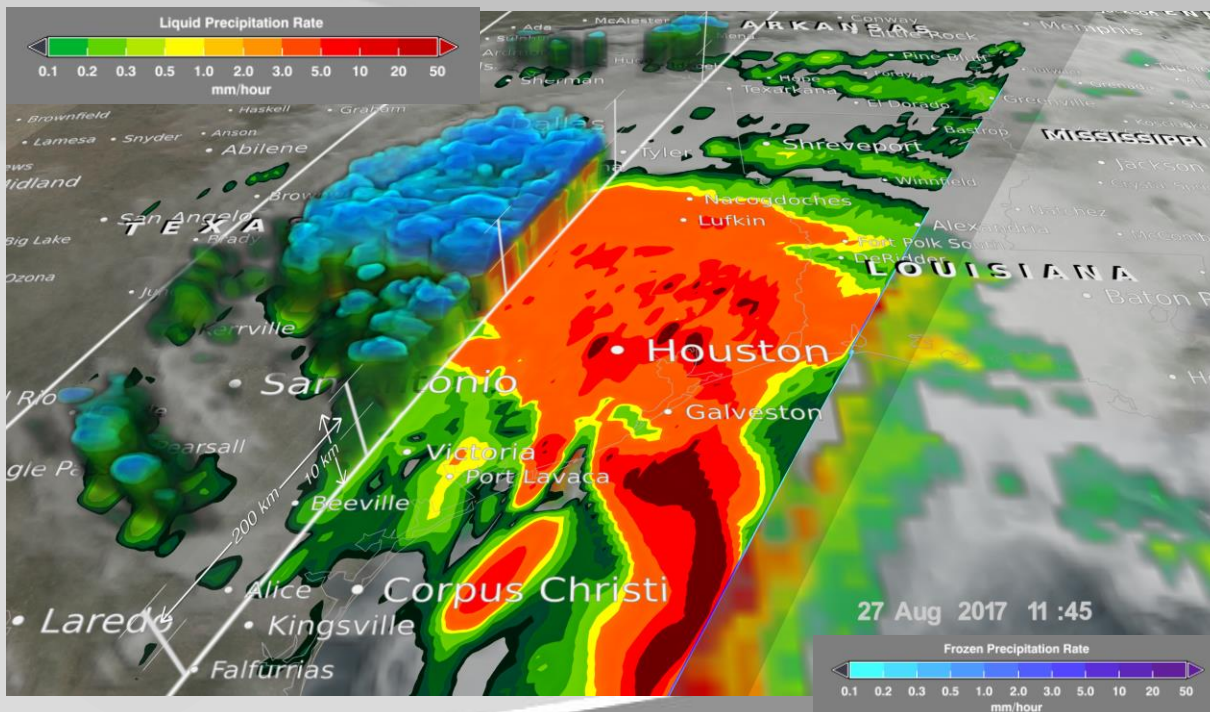
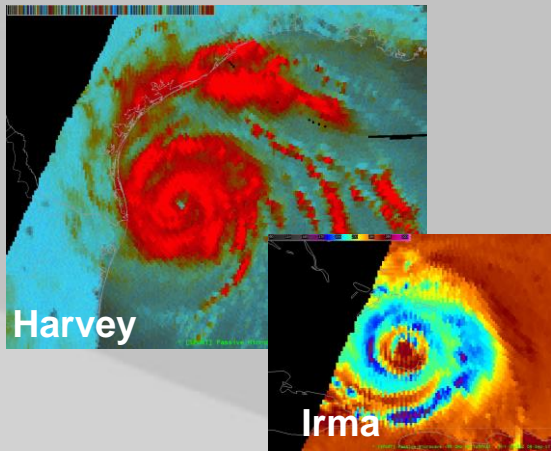




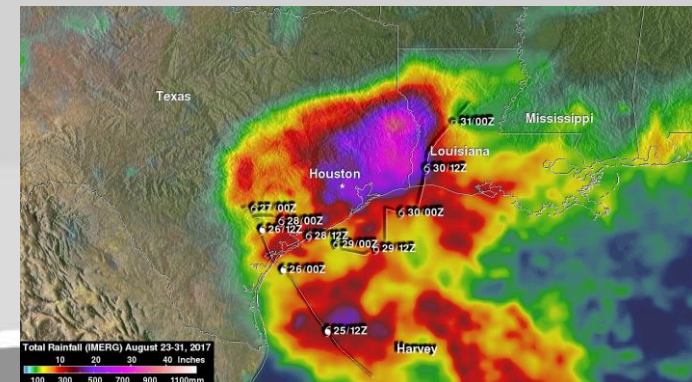
# Monitoring Hurricanes with GPM

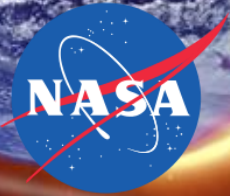
## GPM and Constellation Imagers Map Cyclone Positions and Help Measure Rainfall

- The Global Precipitation Measurement (GPM) Microwave Imager (GMI) and other constellation sensors provide passive microwave imaging of tropical cyclones.
- NASA partnerships help to distribute this imagery to colleagues at NOAA/NWS National Hurricane Center and Naval Research Lab, where imagery is used to help identify center of location and internal structure.



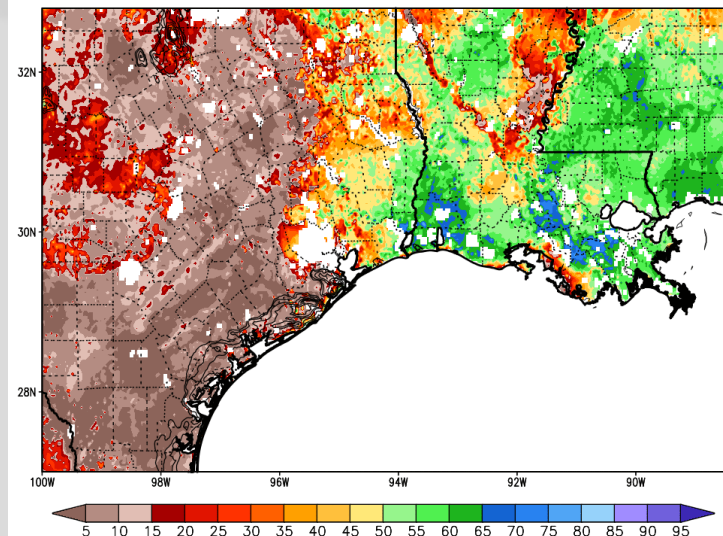
GPM also reveals three-dimensional structure and IMERG integrates rainfall over time to assess scope and impact of inland flooding, particularly where radar is not available.





JPL/CalTech and NASA Earth Observatory

0–100 cm Relative Soil Moisture (available water; %) valid 10z 25 Aug 2017  
Precipitation in previous hour (1,2,5,10,15,20,25 mm contours)



NASA Marshall / Short-term Prediction Research and Transition (SPoRT) Center

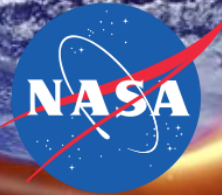
## NASA mission data and models capture impacts of rainfall on soil moisture and greater likelihood of flooding

Data from the Soil Moisture Active Passive (SMAP) mission (top) capture significant increases in soil moisture across southeastern Texas following Harvey, with similar observations available for other tropical cyclones.

Combined with other atmospheric forcing and rainfall data sets, the NASA Land Information System (LIS) to create higher spatial resolution maps of soil moisture prior to and during Hurricane Harvey.

Soil moisture increases are used by partners to assess flood-prone areas and other agricultural applications.





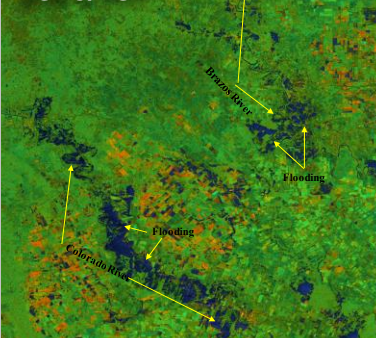
# Synthetic Aperture Radar Mapping

**Texas  
Flood Proxy Map  
(Hurricane Harvey)**



JPL/ARIA

**30 August 2017  
MSFC/ASF**

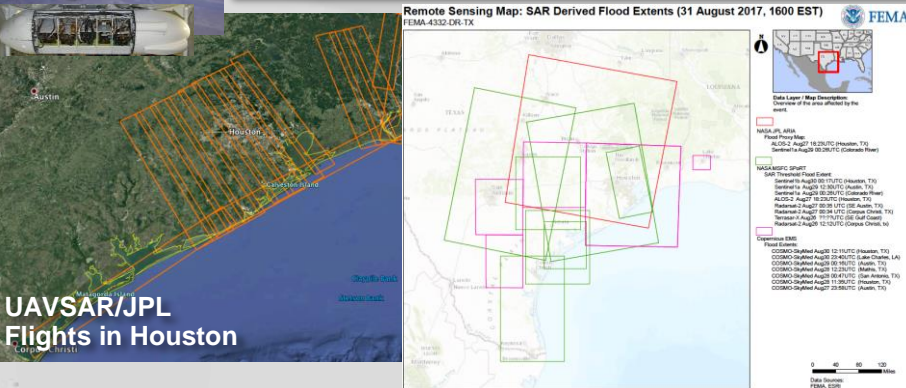


**Puerto Rico  
Damage Proxy Map  
(Hurricane Maria)**

JPL/ARIA



**UAVSAR/JPL  
Flights in Houston**

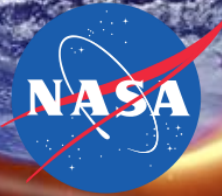


**NASA scientists apply SAR remote sensing techniques to map flood extents to inform partner damage analysis**

Teams across NASA including the JPL Advanced Rapid Imaging and Analysis (ARIA) team, NASA Marshall in partnership with the Alaska Satellite Facility, NASA Goddard, and others provided SAR analysis for flood extent and damage mapping shared with partners including USGS, the Charter, FEMA, National Guard, and others.

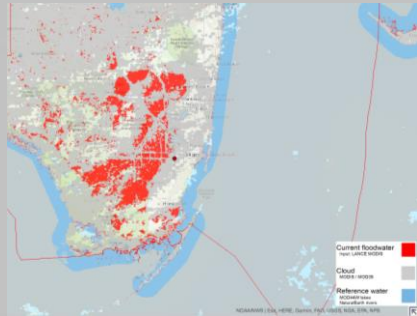
Specific to Harvey, NASA provided flights of UAVSAR led by JPL that assisted the State of Texas with rapid mapping of flood evolution in the Houston metro area.

Multiple SAR scenes via  
Charter/USGS/HHDS in partner analysis

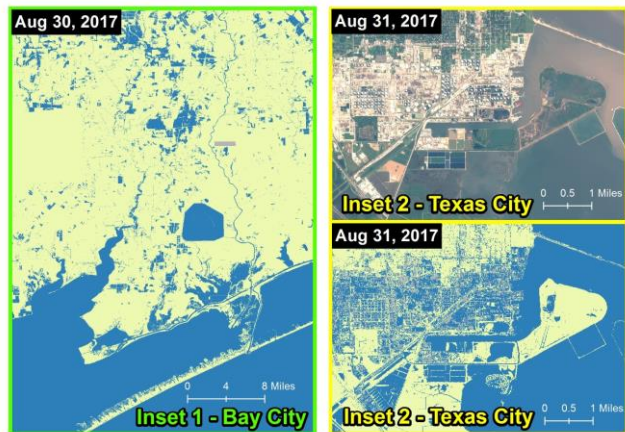


# Optical Remote Sensing and Mapping

NASA NRT Global Flood Mapping  
13 September 2017



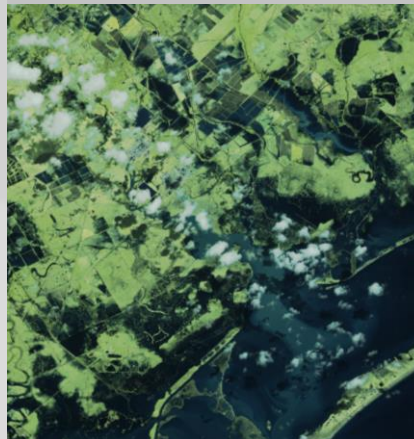
SPOT 6/Worldview 2 Imagery  
30/31 August 2017



NASA team members leverage routine mapping from MODIS for mapping flood extent, and remote sensing expertise to provide additional mapping through HDDS and other providers.

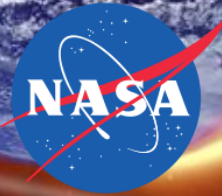
- Routine remote sensing of flood extent via MODIS provided by team members at NASA Goddard
- Other optical data including SPOT, DigitalGlobe Worldview, and others provided by HDDS used to derive various indices and map floods to build upon SAR and other analysis for end users partners

Worldview 2  
30 August 2017



MSFC/UAH and SERVIR collaboration





# Monitoring Nighttime Lights

NASA GSFC and  
Earth Observatory

Baseline

September 27-28

Nighttime Lights

Less

More

Luis Muñoz  
Marín Airport

San Pablo  
Hospital

— PR-1

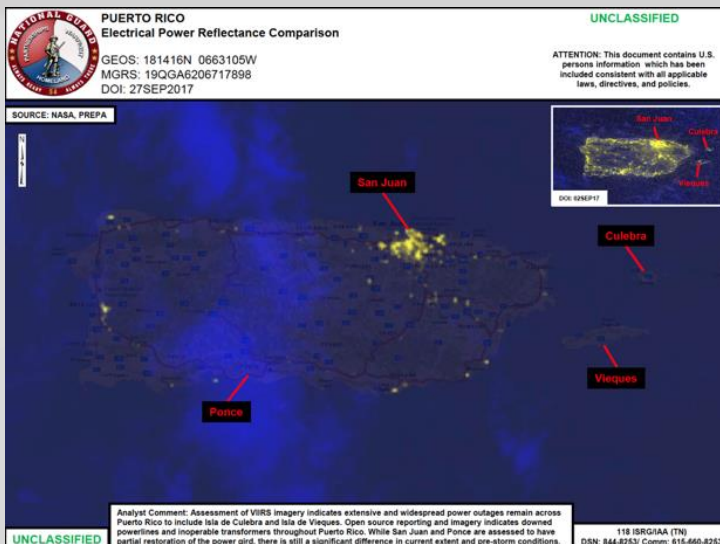
Caguas —

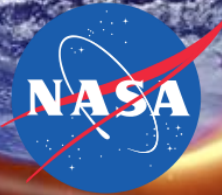
5 km

**NASA/NOAA Suomi-NPP VIIRS data and nighttime light imaging documents extensive loss of light across Puerto Rico, providing situational awareness and opportunity to monitor recovery.**

NASA's Black Marble (below) and Black Marble HD (above) combine VIIRS data and analysis over time to capture departures from normal and current light conditions in the context of real-time cloud cover.

Delivery of products to partners, along with guidance on interpretation, assists with situational awareness and other response decision-making.





# Response Timeline: Harvey

## NASA Response and Engagement Timeline

### Hurricane Harvey (Aug-Sept 2017)

Forecasts for Harvey identify impacts to U.S. mainland, NASA team activates for coordination calls, product generation, and end-user engagement



NASA, NOAA, ESA, International Space Station, and Charter data used collaboratively to map flooding from SAR/optical

Charter/RadarSat-2 Flood Map

Sentinel 1A ARIA Flood Proxy Map (Hurricane Harvey)

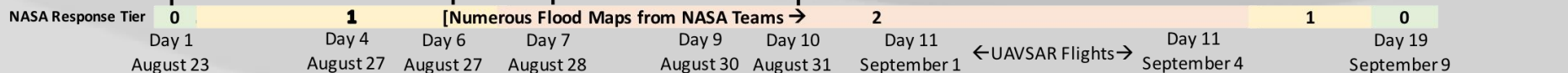
30 August 2017

ALOS-2 Flood Proxy Map

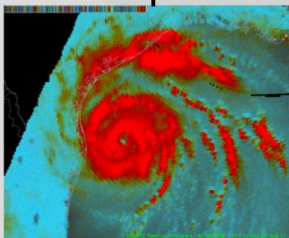
Modeling disaster impacts in Houston metro

Use of NASA Black Marble HD product to explore power outages during post-Harvey flooding

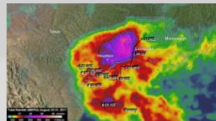
Nighttime Lights: Tracking Power Outages Houston, TX – Post-Harvey



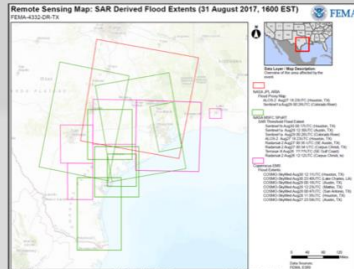
Daily calls begin to coordinate NASA team in generation of products, engagement of funded PIs, and coordination with federal end user partners including FEMA, USGS, National Guard, and others.



NASA's GPM helps track Harvey with data provided to NOAA/NWS and NHC



GPM maps the record-setting rainfall in SE Texas from Harvey

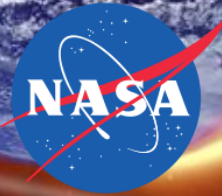


NASA team collaborations provide *over a dozen* detailed flood maps from SAR used by FEMA's geospatial team



NASA provides daily flights of UAVSAR from September 1-4 to rapidly map evolving flood impacts





# Response Timeline: Irma

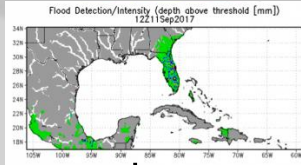
## NASA Response and Engagement Timeline

### Hurricane Irma (Sept 2017)

NASA team initiates response in collaboration with end user partners focused on preparedness and recovery from Hurricane Irma



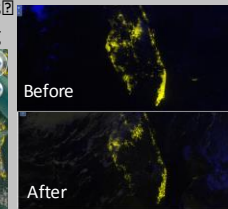
Partners model likely flood and inundation impacts from Irma's predicted rainfall



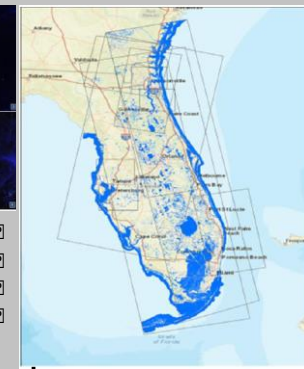
Preliminary mapping of flooding in Key West via ESA Sentinel-1



SAR damage proxy maps generated from ESA Sentinel-1 to identify changes resulting from Irma's winds and flooding



Daily maps of nighttime lights to help understand power loss and recovery

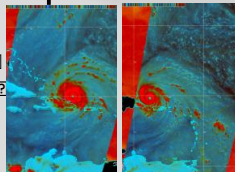


NASA team contributed numerous SAR/optical flood and damage maps to FEMA along with other ESA and commercial partners

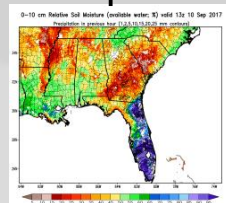
NASA Response Tier



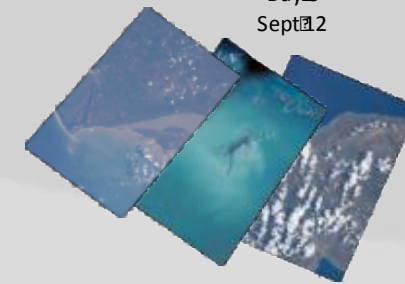
Continuing from Harvey, daily coordination calls and user engagement with partners including FEMA, National Guard, USGS and others



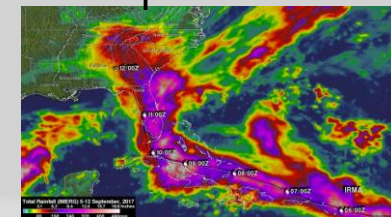
GPM and constellation satellites provide mapping of Irma's track through the Caribbean, data to NOAA/NHC, NRL



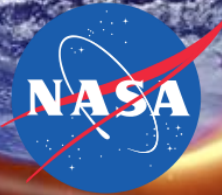
Daily NASA LIS captures saturated soils and flooding in FL/SE



ISS astronaut photography provides imagery of impacts in the Caribbean/Florida



GPM/IMERG rainfall product measures rainfall across the impacted area



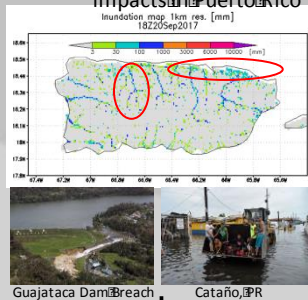
# Response Timeline: Maria

## NASA Response and Engagement Timeline

### Hurricane Maria (Sept-Oct 2017)

NASA team initiates response in collaboration with end user partners focused on preparedness and recovery from Hurricane Maria

Flood modeling by partners for impacts in Puerto Rico



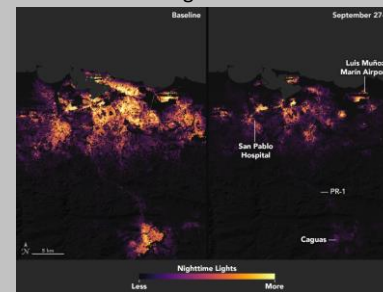
Daily FEMA Remote Sensing and Geospatial Teams incorporate NASA information into daily briefings and use analysis to understand recovery needs.



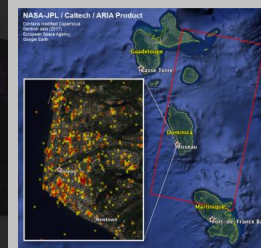
ESA Sentinel SAR imaging used to produce damage proxy maps for affected regions in Puerto Rico



NASA Black Marble HD captures Puerto Rico outages, used by partners and major media to keep public informed of local power conditions on neighborhood scales.



Damage proxy maps extended to Dominican using SAR data



NASA Response Tier 0

Day 1  
Sept 18

Continuing from Irma, daily coordination calls and user engagement with partners including FEMA, National Guard, USGS and others



GPM and Constellation satellites map Maria, data for NOAA/NHC and NRL

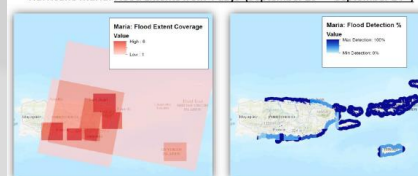
Day 3  
Sept 20



Flood mapping by the NASA team using SAR and optical assets

Day 4  
Sept 21

Hurricane Maria: Flood Extents from 4 days (September 20<sup>th</sup> - September 24<sup>th</sup>)



Multiple flood-mapped scenes from NASA and commercial partners combined by FEMA to assess flood extent

Day 7  
Sept 24

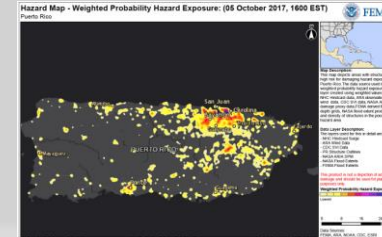
Daily Power and Light Analysis w/ Black Marble

Day 10  
Sept 27



NASA Black Marble by National Guard teams for daily situational awareness.

Day 13  
Sept 30



NASA team damage proxy and flood information synthesized with other FEMA data to map impacts

Day 14  
Oct 2

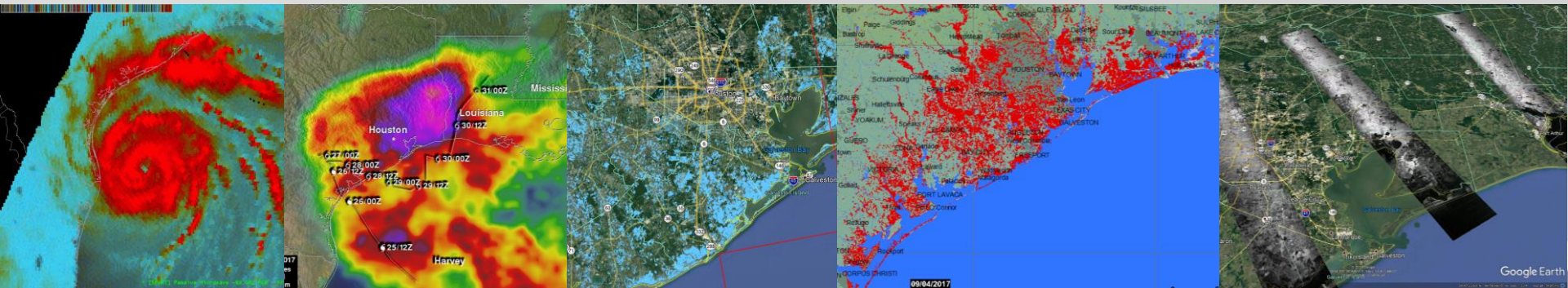
Day 15  
Oct 3

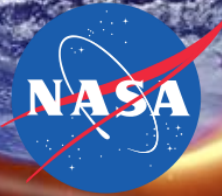
Combined, support for Harvey, Irma, and Maria included over 60 days of NASA team activity...





- NASA's Earth Science Disaster Response Team provided numerous products and assistance during Hurricanes Harvey, Irma, and Maria
- Through collaboration across NASA Centers and partners, the broader team provided numerous remote sensing and modeling capabilities to end user partners, along with close end-user collaborations that assisted end users with incorporating those products and maps into their decision-making and analysis process.
- Ongoing and future activities will continue to bolster collaborations with end users including GIS services for delivery of data and training, continued after-action reviews, and further improvements in event coordination.





## ■ NASA Disasters Web Page:

- <http://disasters.nasa.gov>

## ■ NASA Applied Sciences Program:

- <http://appliedsciences.nasa.gov>



## ■ Contact Information:

- Jordan Bell, [jordan.r.bell@nasa.gov](mailto:jordan.r.bell@nasa.gov)
  - Research Associate, UAH, NASA Marshall Space Flight Center
- Andrew Molthan, [andrew.molthan@nasa.gov](mailto:andrew.molthan@nasa.gov)
  - Research Meteorologist, NASA Marshall Space Flight Center
- David Green, [david.s.green@nasa.gov](mailto:david.s.green@nasa.gov)
  - Program Manager, NASA Applied Science Disasters Program